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Axial Crushes Simulation of Thin-Walled Square Aluminum Alloy 6061-T5 Foam-Filled Section

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Abstract

This paper deal with numerical study of the dynamic impact of axial crushing on thin-walled extrusion aluminum alloy 6061 and polystyrene foam-filled tubes square cross-section. Non-linear dynamic-impact simulation was done using finite element software's package as well on foam-filled model. Non-linear dynamic finite elements were carried out to simulate buckling and crushing phenomenon in the crushed event. Influence of fillers on the energy absorption behavior of square and thin-walled metal tube extrusion aluminum alloy 6061 estimates empty and foam-filled examined. Three main decay modes have been identified for the model is crushes, for example, diamond compound symmetry, axisymmetric concertina mode of formation and mixing times. Three different arrangement foam-filled inner tube columns has been examined and investigated.

Keywords: Thin-Walled Structure, Finite Element Modeling, Progressive Damage, Foam-Filled.

1. Introduction

Many types of device are employed to absorb high energy releases in containment structures such as pressure vessels and in transport systems such as cars, trains and lifts which are subject to collisions or impacts [1]. These devices usually have the advantage of being cheap, light weight, easy to construct and are able to sustain a high energy absorption density with constant loading before failure [2]. They may take the

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form of groups of thin walled tubes, of uniform or tapered wall thickness, with circular or polygonal cross-sections under axial impact loading, which have desirable stroke dependent characteristics [3]. The purpose of this study is to explore the effect of impact velocity on the peak load and energy absorption for double square tubes empty and foam-filled. Figure 1 shows progressive buckling, for example the sequential formation of adjacent local folding patterns of the deferent specimens [4]. The double cell arrangements were shown to be particularly efficient crush elements, as long as global failure (Euler buckling) could be avoided [5]. The study also showed that double cell arrangements may be preferable to single tube based on energy absorption because the inner tube is more mass efficient.

1.1. Material Models and Properties

Two types of models were analyzed in this study which is empty and foam-filled tubes. The empty square tube models were arranged as double tubular ones, material of aluminum 6061-T5 alloy was used to determine the crushing behavior and having of 60 x 60 mm outer diameter arrangement with inner tube were 50 x 50, 40 x 40, 30 x 30 mm and 1.0, and 2.0 mm wall-thickness. The foam-filled models were carried out from two tubes having outer wall from the same material as empty tube profiles as well as inner wall of tube. The inner tube has varied with three different length width including 50 x 50, 40 x 40, 30 x 30 mm and 1.0 and 2.0 mm wall-thickness but constrained at the same thickness as well as outer tube thickness. All sections had a length of 150 mm. The empty tube sections were tested as empty and foam-filled tube profiles only with the foam in between inner and outer tube wall. Fig.1 illustrates typical test model geometry, whereas Fig. 2 presents tensile stress-strain data curves of the used materials. In this study the velocity dynamic of impact was applied at 20, 30 and 40 m/s axially onto the frontal crash flat plate analytical rigid surface.

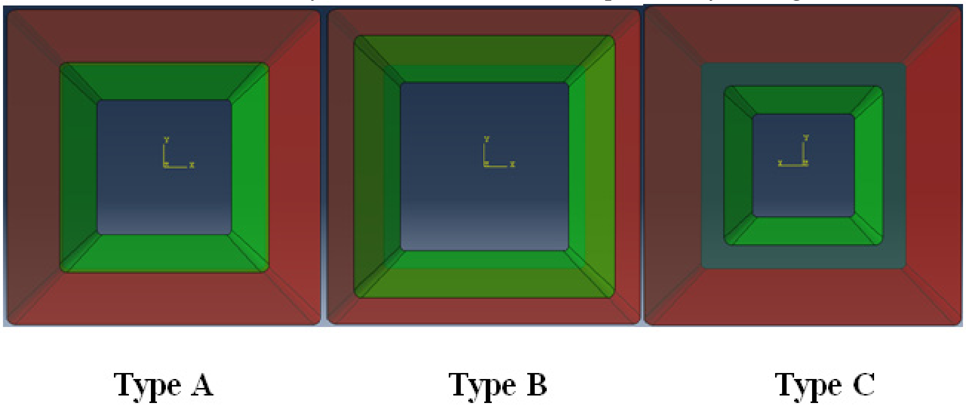

Fig. 1. Test model geometry of type A, B and C

Table 1.Dimension of column finite element modeling

Type (tubal)	*Length (mm)*	*Width (outer) (mm)*	*Width (Inner) (mm)*	*Velocity (m/s)*	*PolystyreneFoam Density*	*Thickness (mm)*
A	150	60 x 60	30 x 30	20, 30, 40	0, 100	1.0, 2.0
B	150	60 x 60	40 x 40	20, 30, 40	0, 100	1.0, 2.0
C	150	60 x 60	50 x 50	20, 30, 40	0, 100	1.0, 2.0

2. Result and Discussion

With respect to the failure modes of test series empty and polystyrenefoam filled square extruded aluminum 6061 alloy profiles with small cross-sectional dimensions the numerical revealed that progressive buckling could almost exclusively be observed for some empty tubes and the foam filled crush elements with square cross-sections in Fig.3 to 5. All square empty and foam-filled tubes profiles of this analysis test series having a foam density than the square ones rather showed local progressive damage, but not typically progressive, deformation behavior, where the formation of folds began at different locations, generally not in a sequential manner [6]. Furthermore, these element models buckled extensionally with all folds moving outwards, which is obviously caused by the presence of the foam core.

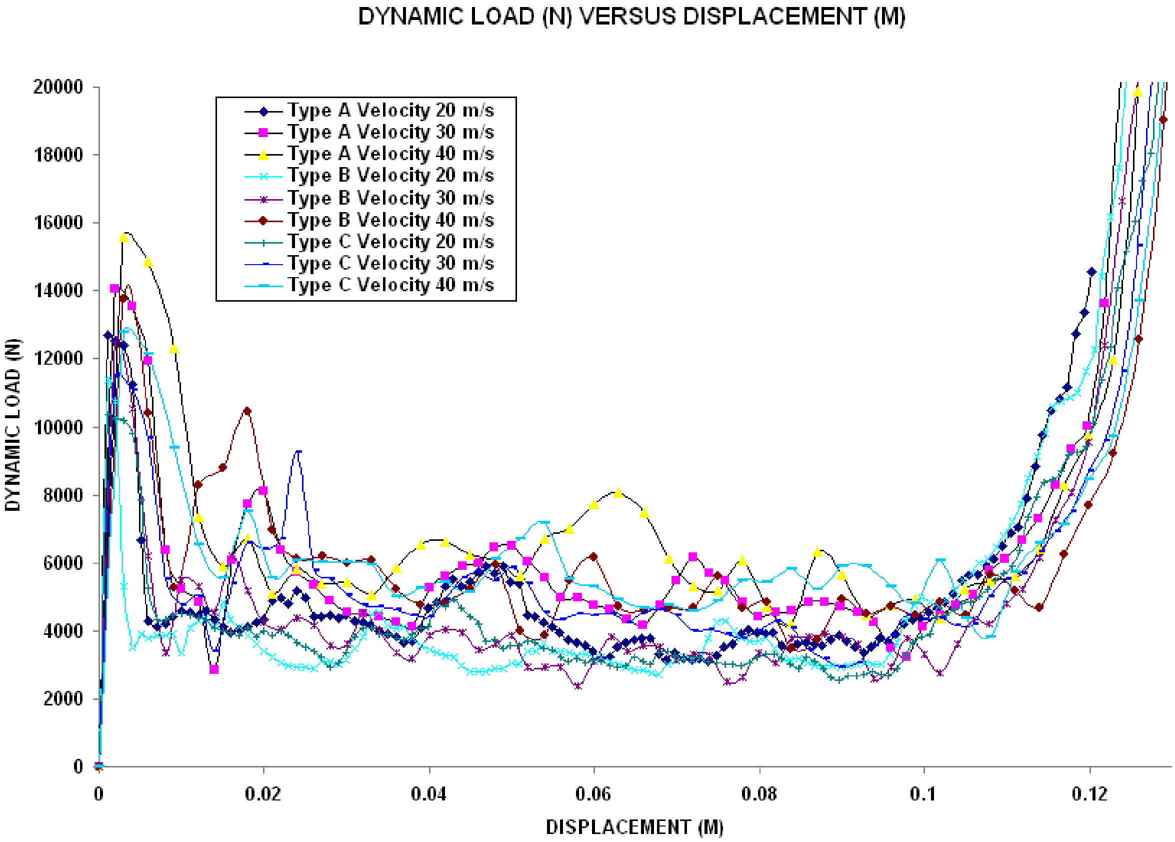

Fig. 2. Dynamic load (N) versus displacement (m) type of A, B and C foam-filled tube square profile;

The extensional deformations are also evident from the dynamic load compression displacement curves in Fig.3(a), because the load fluctuations are much more pronounced. Filling polystyrenefoam inside of the tubes was in general accompanied by shorter wavelengths of the individual folds which is holds true for all element model test series. Within element model test series empty and foam-filled square tubes, which were arranged in different ways, empty, foam-filled tubes, and arrangement with dimension of inner square tube profile, were analyzed.

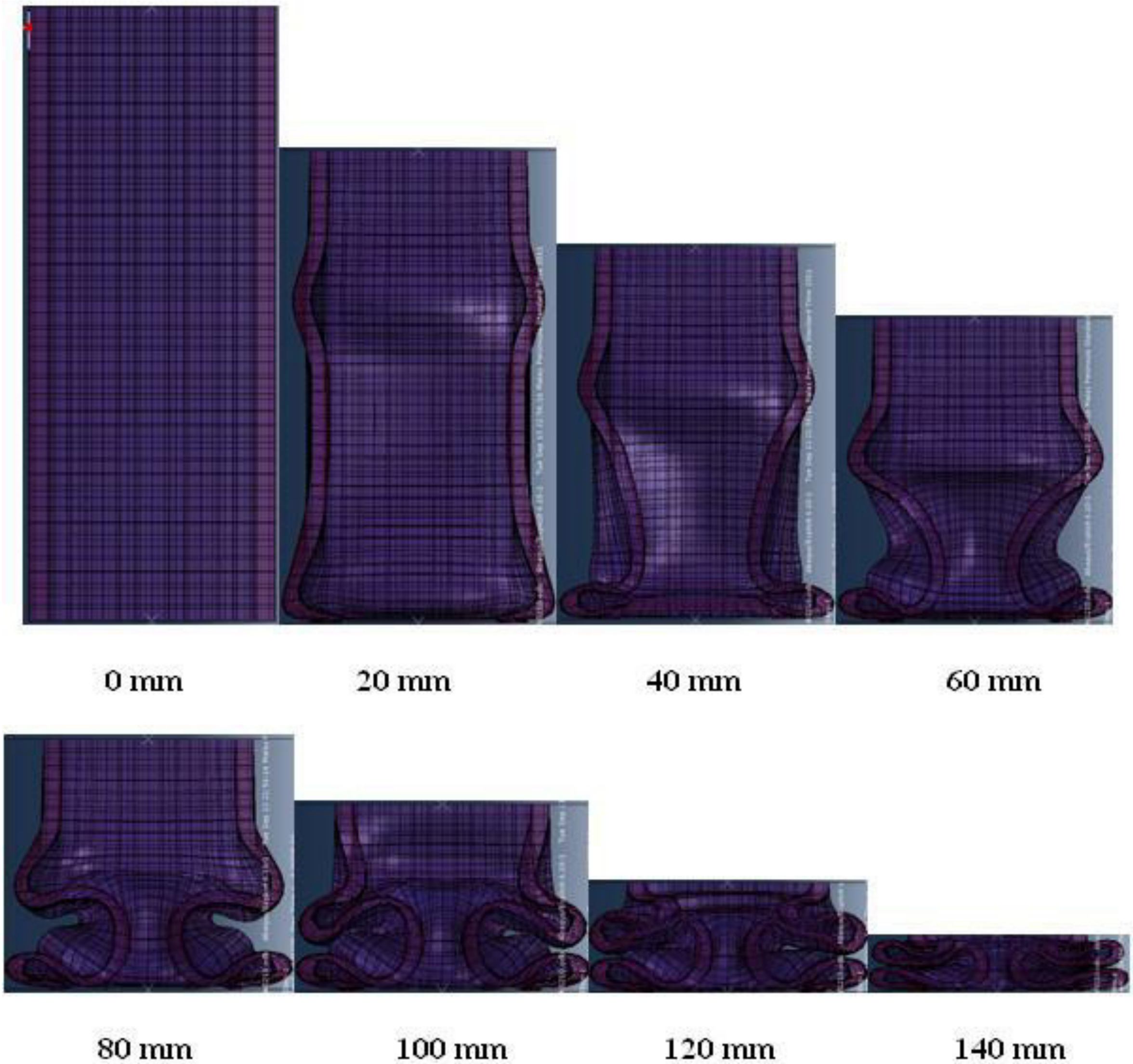

Fig. 3. Deformation pattern type of C foam-filled tube square profile (Wall-Thickness = 1 mm: Velocity = 20 m/s)

The inner material profile in Fig.3(b) which is 50 x 50 mm was used inside the outer square filling with polystyrenefoam with 100 kg/m^3 density. The typical progressive buckling characteristics, which could be observed in most numerical analysis of this test series of wall thickness 1 and 2 mm as well as variable dynamic impact loading of 20, 30 and 40 m/s, are evident from the deformed elements shown in Fig.5. The type of C foam-filled tube square profile also reveals the higher densification in the outer region of the foam core due to a multiaxial state of compression illustrated resulting from foundation effects of the foam with respect to the profile. Global failure was observed only for the foam-filled tube foam filled elements. This can be traced back to global buckling of the slender inner profiles, leading to overall buckling of the whole arrangements. All filled element modeling that deformed locally began to buckle in an extensional mode, but after the formation of some folds most switched to an inextensional mode, which is typical for the empty profiles of this type of C. The measured dynamic loads versus displacement curves from Fig. 4 also clearly display the effects of the change of deformation modes. The foam-filled tube element model show a pronounced load fluctuation during the load cycles, owing to the extensional folding modes, which is followed by minor differences between maximum and minimum loads due to the inextensional buckling deformations of the extruded aluminum 6061 alloy tubes.

Furthermore, the dynamic mean load versus displacement curves reveal a distinct quasi-steady progress of the crushing forces which is fluctuating around a more or less constant value, provided that the average foam density is not too high. The ascending slope of the force level of foam-filled tube type of C which square inner profile of 50 x 50 mm, however, is due to the foam behavior itself. As a result, from Fig.4 and 5, the element model analysis apparent foam density of 100 kg/m^3, a regular progressive buckling behavior, dominated by inextensional folding modes and, hence, with not too large energy fluctuations, while retaining marked efficiency improvements with respect to the mean load. Because the stroke efficiency should also remain high for such densities, distinct improvements of the whole energy absorption capacity can be expected. To our experience this does not only apply to empty crush elements with square cross-section although the improvements are most pronounced in this case of foam-filled tube profile.

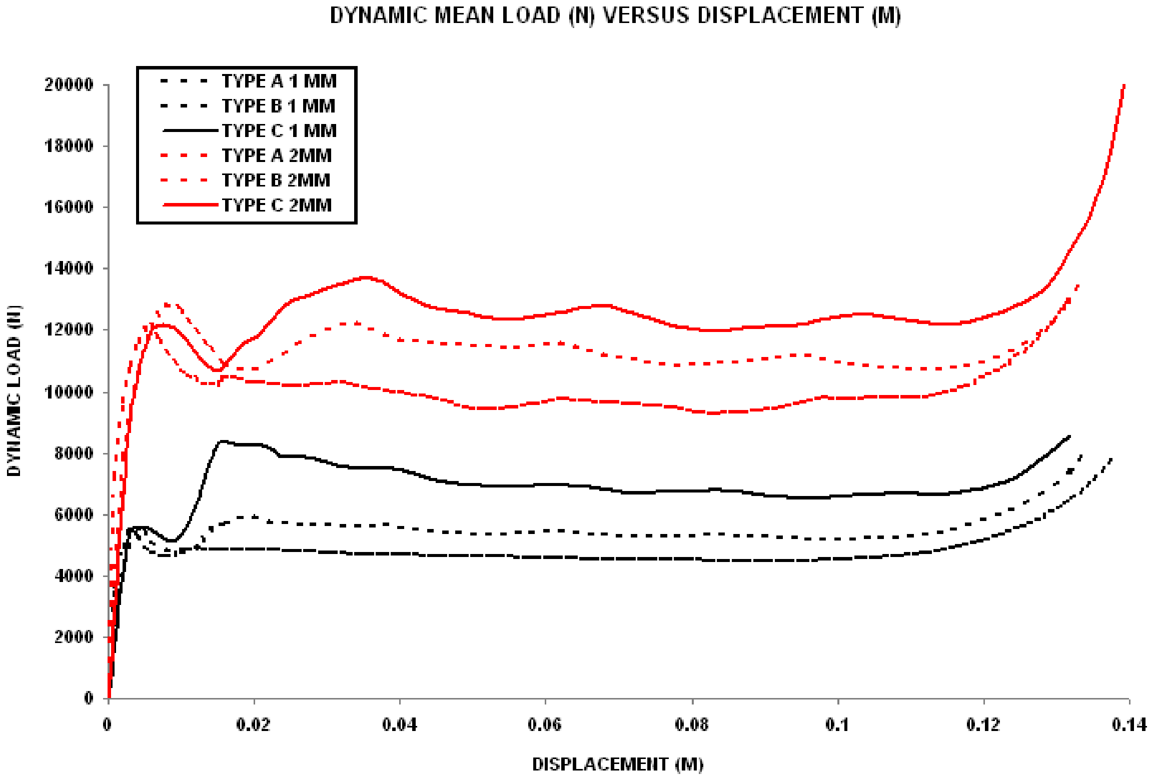

Fig. 4. Dynamic mean load (N) versus displacement (m) empty tube square profile (Wall-Thickness = 1 and 2 mm: Velocity = 20 m/s)

It can be seen in the Fig.5; the velocity increase when a crush faster and progressively even on empty absolutely in foam-filled tube. It can be seen that the type of C apparent the highest performance of energy absorption capability. However the cross-sectional dimensions have to be selected carefully in order to avoid global failure of one of the tubes. Such metallic structures are, therefore, expected to be of advantage mainly in structures that have to resist considerable compressive load, so that larger cross- sectional dimensions have to be applied in any case.

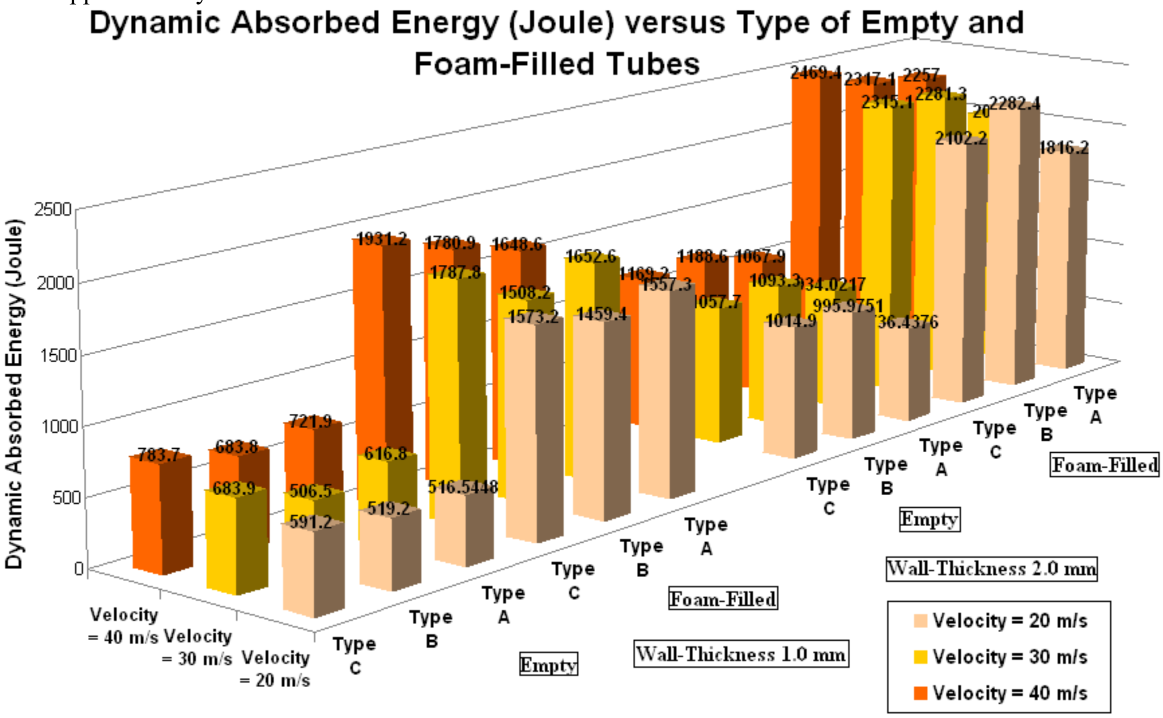

Fig. 5. Dynamic absorbed energy versus type of tube profile empty and foam-filled tube Cross-Section

3. Conclusions

The test element results model presented here confirm that the mass related mean load level may considerably be improved by filling tubular members with polystyrenefoam. Provided that the plastic buckling behavior remains characterized by local modes, essential enhancements were obtained for all investigated shapes and dimensions. These improvements may partly be traced back to the axial compression of the foam cores themselves, but interaction efficiency is also play a substantial role that the simple estimates. With respect to the total energy absorption capacity of a given crush element, however, improvements are less pronounced. The reason for this is that the maximal crushing distances, which may be utilized for energy dissipation, reduce with increasing foam densities. Nevertheless, improvements of the mass the investigation of foam-filled tube arrangements revealed that these may be preferable to empty analysis. Furthermore, some basic conditions for the appropriate choice of tube filler combinations could be obtained this way.

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